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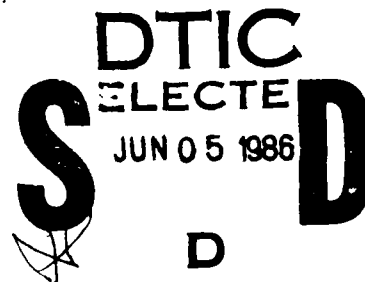
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STUDIES ON TRANSONIC DOUBLE CIRCULAR ARC (DCA) PROFILES OF
AXIAL FLOW COMPRESSOR-CALCULATIONS OF PROFILE DESIGN

by

Y. Ruqun and Q. Zhaoyan

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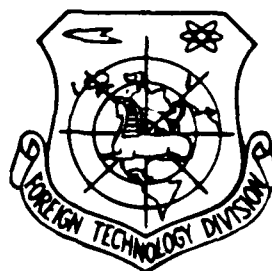
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STUDIES ON TRANSONIC DOUBLE CIRCULAR ARC (DCA) PROFILES OF AXIAL
FLOW COMPRESSOR-CALCULATIONS OF PROFILE DESIGN

Yan Ruqun and Qian Zhaoyan
(North Western Polytechnical University)

In this paper, the concepts and methods for design of high-Mach-Number airfoils
of axial flow compressor are described. The correlation-equations of main parameters
such as geometries of airfoil and cascade, stream parameters and wake characteristic
parameters of compressor are provided. For obtaining the total pressure loss coeffi-
cients of cascade and adopting the simplified calculating method, several curves and
charts are provided by authors. The testing results and calculating values are compar-
ed, and both the results are in better agreement.

1. Preface

The flow of transonic gaseous flow in the compressor cascade is
highly three-dimensional and extremely complicated. Although high
speed, large capacity computers are now available for applications,
it is still quite difficult to solve practical, three-dimensional and
compressible flow problems in the cascade. The design of modern
axial flow compressor's high speed cascade, e.g., the design calcula-
tions of double circular arc (DCA) profile, can be completely carried
out in accordance with the method based partially on experience, i.e.
the method of combining theory and practicality, to find the correla-

tions between various main performance and geometric parameters of this transonic profile under a given operating condition. Then, substituting the various accumulated effective data of the cascade with said profile to solve for the best combination of main performance and geometric parameters of the cascade with this profile, it is possible to design a smaller total pressure loss and higher cascade efficiency in the cascade.

2. Basic Equations

According to Reference [1], the cascade total pressure loss coefficient is:

$$\omega = \widetilde{M}_1 (\sin\beta_1 / \sin\beta_2)^2 (\theta_2 / b \cdot \sigma / \sin\beta_2)[1 - (\theta_2 / b) \cdot \sigma H_2 / \sin\beta_2]^{-3} \cdot 4H_2 / (3H_2 - 1) \tag{1}$$

where the subscript "1" represents the cross section 1-1 at the entrance of the cascade; subscript "2" represents the cross section 2-2 at the wake exit of the cascade. Let $\bar{\theta}_2$ be the momentum thickness parameter in the boundary layer, then

$$\bar{\theta}_2 = (\theta_2 / b) \cdot \sigma / \sin\beta_2 \tag{2}$$

and Equation (1) can be rewritten as:

$$\omega = \widetilde{M}_1 (\sin\beta_1 / \sin\beta_2)^2 \bar{\theta}_2 (1 - \bar{\theta}_2 H_2)^{-3} \cdot 4H_2 / (3H_2 - 1) \tag{3}$$

where $\widetilde{M}_1$ is the Mach Number parameter at the entrance of the cascade,

$$\widetilde{M}_1 = f(M_1) = (1 - 0.5M_1^2)(1 + 0.5M_1^2) \tag{4}$$

For a given cascade, if the Mach Number M_1 at the entrance is known, then the $\widetilde{M}_1$ value can be obtained from the $\widetilde{M}_1$-M_1 curves (Fig. 1) drawn by the authors. β_1 and β_2 are the profile entrance and exit angles, respectively; θ_2/b is the momentum factor of the boundary layer; θ_2 is the momentum thickness of the boundary layer; b is the arc length of the profile; $\sigma = b/t$ is the cascade density; H_2 is the geometric factor of the boundary layer.

In the design calculations of the profile, some of the various main parameters in the above correlation-equations can be selected

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according to theory and practicality; other parameters can be
calculated using this functional correlation to solve for the best
combination. The authors of this article suggest that, since the
calculations of Equation (1) are more cumbersome, the following curves
be adopted to simplify the calculations.

3. Simplified Calculations

In Equation (1), there are two parameters that are relatively
difficult to determine, i.e., the boundary layer geometric factor H_2
and the boundary layer momentum factor $E=\theta_2/b$. For the geometric
factor H_2 within the cascade entrance Mach Number range of $M_1=$
$=0.20 \sim 0.90$, the curves drawn by the authors can be adopted (Fig. 2);
in high Mach Number range, the H_2-M_1 curves in Reference [2] can be
adopted. For the momentum factor E within the cascade entrance
Mach Number range of $M_1=0.20 \sim 0.90$, the curves drawn by the authors
can be adopted (Fig. 3); for the cascade with double circular arc
profile in the transonic range, the momentum factor E of the cascade
with double circular arc profile and the stream Mach Number curves in
Fig. 4 can be adopted, based on the actual situations. With the sets
of curves in Fig. 1 through Fig. 4, it is much easier to use Equation
(1) herein to calculate total pressure loss coefficients of cascades
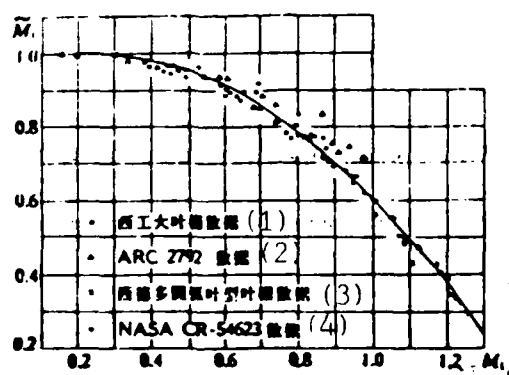with double circular arc profile or other similar cascsades of tran-
sonic profile.

Fig. 1. $\widetilde{M}_1-M_1$ Curve
Key: (1) North Western Polytechnical University Cascade Data;
(2) ARC 2792 Data; (3) West Germany's Data for Cascade with Multiple
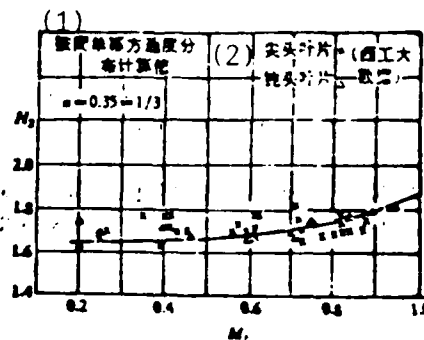Circular Arc Profile; (4) NASA CR-54623 Data.

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Fig. 2. H_2-M_1 Curve
Key: (1) Calculating Values of Velocity Distribution Using the Simplified Calculating Method n≈0.35±1/3; (2) Pointed Blade x, Blunt-head Blade " (North Western Polytechnical University Data).
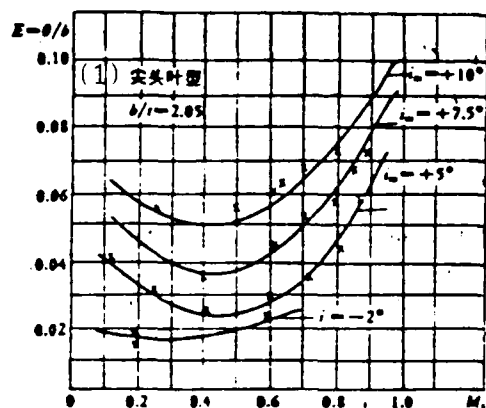

Fig. 3. E-M_1 Curves
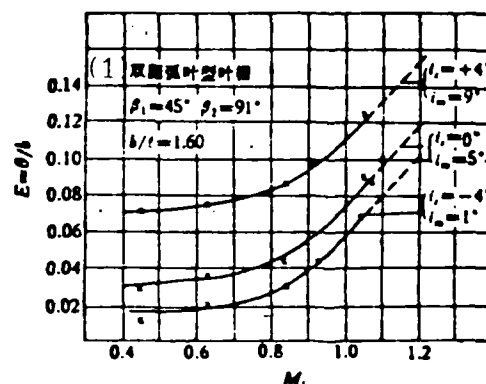Key: (1) pointed profile.

Fig. 4. E-M_1 Curves for cascade with double circular arc profile
Key: (1) Cascade with double circular arc profile.

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The comparison between the simplified calculating values and the testing values: based on a given cascade with double circular arc profile under different operating conditions $(M_1 - 0.4 \sim 1.2;\ i_- - 0 \sim +7.5°)$, simplified calculations adopting Equation (1) and using the curves herein were conducted to obtain various total pressure loss coefficient $\bar{\omega}$ values. Meanwhile, these calculated $\bar{\omega}$ values were compared with the testing values of total pressure loss coefficient $\bar{\omega}$ at the average radius of the double circular arc stator reported in Reference [3], and it was found that the values obtained from both methods were in better agreement. Therefore, the various main parameters of the correlation-equations derived herein for cascades with transonic profile are valid. In the meantime, the effects of adopting the curve method to simplify calculations of total pressure loss coefficient under different operating conditions for cascades with double circular arc profile or other similar cascades with transonic profile are relatively satisfactory, and the scope of applications for this approach is much wider.

REFERENCE

[1] 严汝群、钱振堆: "高亚音速二元叶栅损失的理论分析和实验研究",工程热物理学报, 2, (1981).

[2] Warner L. Stewart, Warren J. Whitney, Robert Y. Wong: "A Study of Boundary-Layer Characteristics of Turbomachine Blade Rows and their Relation of Overall Blade Loss", Trans. ASME 82D, 3, (1960).

[3] M. J. Keenan, at al.: "Experimental Evaluation of Transonic Stators Data and Performance Report Double-Circular-Arc Stators". NASA CR-54623, (1968).

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